Name _____ Class _____ Date _____

CHAPTER 7 Chemical Reactions

SECTION 4

Reaction Rates and Equilibrium

KEY IDEAS

As you read this section, keep these questions in mind:

- How can you increase the rate of a reaction?
- What does a catalyst do?
- What happens when a reaction goes backward and forward?

What Are Some Ways to Increase the Rate of a Reaction?

Chemical reactions can happen at different rates, or speeds. You can change the speed of a reaction by changing certain factors. You may already know some ways to change reaction rates. In fact, you may use the factors that affect reaction rates every day.

Think about the following observations and hypotheses:

- A potato slice cooks in 5 minutes at 200 °C. A potato slice cooks in 10 minutes at 100 °C. Thus, potatoes cook more quickly at higher temperatures.
- Potato slices cook in 10 minutes. A whole potato cooks in 30 minutes. Thus, many small pieces of potato cook more quickly than a whole potato.

These observations reveal changes in the speed of chemical reactions. In both situations, the contact between particles of potato and particles of boiling water was increased. When contact between particles increased, the reaction (cooking) happened more quickly. This relationship reflects a general principle: ☑

> Anything that increases contact between particles will increase the rate of a reaction.

Factors that affect the rate of a reaction include:

- temperature
- concentrations of the reactants
- surface area of the reactants
- particle mass, shape, and size
- pressure

READING TOOLBOX

Summarize As you read, make a chart that shows different ways to speed up a chemical reaction. In your chart, include columns for examples and for explanations of how each method increases reaction rate.

Talk About It

Discuss In a small group, talk about other chemical reactions you may see or use in your daily life. Do you use any methods to speed up the reactions?

READING CHECK

1. Identify In general, what will increase the rate of a chemical reaction?

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TEMPERATURE AND REACTION RATE

When you heat food, you add energy to the particles. Cooking at higher temperatures cooks food more quickly. Why? Chemical reactions are faster at higher temperatures. ☑

READING CHECK

2. Describe What is the relationship between temperature and reaction rate?

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Bread stored at room temperature | Bread stored in the freezer

Cooling food slows down the chemical reactions that cause food to spoil.

Recall that as particles move more quickly, temperature increases. An increase in temperature can speed up a reaction in two main ways:

1. Faster-moving molecules collide more frequently.
2. Faster-moving molecules transfer more energy when they collide.

Fast-moving particles in a substance at a high temperature collide more frequently. They are more likely to react because they collide with more energy to break bonds.

CONCENTRATION AND REACTION RATE

In most cases, the rate of a chemical reaction increases when you increase the concentrations of the reactants. Consider what would happen if you doubled the concentration of reactants. There would be twice as many collisions between reactant particles. ☑

READING CHECK

3. Explain Why does increasing concentration increase reaction rate?

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Recall that if you add baking soda to vinegar, gas bubbles form. If you mix some water with the vinegar first, you make a less concentrated solution. When you add the baking soda, the same amount of bubbles will not be produced as quickly. Thus, a lesser concentration of reactants decreased the reaction rate.

SURFACE AREA AND REACTION RATE

If you place a whole potato in boiling water, only the surface of the potato touches the water. The energy from the water molecules has to go through the whole potato in order for the potato to cook. However, if you cut up the potato and put the pieces into boiling water, you expose more of the potato. This causes the potato to cook more quickly.

Many small pieces of potato have more surface area than one whole potato. Increasing the surface area of a reactant speeds up a reaction.

When you divide a solid into pieces, the total surface area becomes larger.

LOOKING CLOSER

4. Explain How does dividing a solid into smaller pieces affect surface area?

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MASS AND REACTION RATE

Recall that according to the kinetic theory of matter, more massive particles move more slowly than less massive ones at the same temperature. Because they move more slowly, the more massive particles collide less frequently with other particles. Thus, reactants with massive particles will not react as readily as those with less massive particles. ☑

READING CHECK

5. Explain Why do more massive particles collide less frequently than smaller particles do?

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SIZE, SHAPE, AND REACTION RATE

Particles of reactants must be in a certain position relative to other particles in order to react. Large reactant particles generally have more branches or bulky parts than smaller particles. Therefore, larger particles cannot get into the correct position as quickly as smaller particles. Thus, reactants with larger particles generally do not react as readily as those with smaller, simpler particles.

PRESSURE AND REACTION RATE

The concentration of a gas is the number of particles in a certain volume. A gas at higher pressure has a higher concentration than the same amount of gas at lower pressure. Gases react more quickly at higher pressures. Why? ☑

Gas at high pressure is squeezed into a smaller space. When gas particles have less space to move, they collide more frequently with one another. More frequent collisions cause more reactions.

READING CHECK

6. Identify What is the relationship between gas pressure and reaction rate?

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What Is a Catalyst?

Chemists add substances called catalysts to many chemical reactions to change the speed of a reaction. A **catalyst** is a substance that speeds up or slows down a reaction but is not changed by the reaction. Catalysts that slow down reactions are also called *inhibitors*. ☑

READING CHECK

7. Explain Why may a chemist add a catalyst to a chemical reaction?

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Different catalysts work in different ways. Most solid catalysts speed up reactions by providing a surface where the reactant particles can meet and react.

Various industries use catalysts. For example, catalysts are used to help make ammonia, to process crude oil, and to make plastics. Catalysts can be very expensive. However, because they are not used up by a reaction, they can be cleaned or renewed and reused.

To help reduce air pollution, cars have special devices called catalytic converters. A *catalytic converter* reduces pollution by speeding up reactions that break down harmful substances into harmless ones. In general, platinum is the catalyst in catalytic converters.

LOOKING CLOSER

8. Identify What reactions do catalytic converters catalyze?

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A car's catalytic converter reduces air pollution by helping pollutant molecules react to form less harmful substances.

What Is an Enzyme?

Catalysts are very important in living things. A catalyst produced by a living thing is called an **enzyme**. A reactant that is acted on, or *catalyzed*, by an enzyme is called a **substrate**.

An enzyme has an active site that fits a particular substrate.

The substrate undergoes a reaction.

The substrate then leaves the active site and another substrate enters the active site.

An enzyme is a large molecule that has one region on its surfaces called the *active site*. Only a particular substrate can fit into the active site of a particular enzyme. Only a substance that can fit into this active site can participate in a reaction catalyzed by the enzyme. Therefore, each enzyme is very specific and catalyzes only one reaction or one set of similar reactions. ☑

Enzymes are very efficient. The cells of most organisms contain an enzyme called catalase. *Catalase* breaks down hydrogen peroxide, which is poisonous to cells. In 1 min., one molecule of catalase can catalyze the decomposition of 6 million molecules of hydrogen peroxide.

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

Recall that an enzyme is not affected by the reaction it catalyzes. Therefore, the same catalase molecule can catalyze the decomposition of H_2O_2 molecules over and over again.

READING CHECK

9. Explain Why does an enzyme catalyze only one reaction or a set of similar reactions?

Critical Thinking

10. Apply Concepts In the decomposition of hydrogen peroxide catalyzed by catalase, which substance is the substrate?

Common Enzymes and Their Uses

Enzyme	Substrate	Role of the enzyme
Amylase	starch	to break down starch into smaller molecules
Cellulase	cellulose	to break down long cellulose molecules into sugars
DNA polymerase	nucleic acid	to build up DNA chains in cell nuclei
Lipase	fat	to break down fat into smaller molecules
Protease	protein	to break down proteins into amino acids

What Is Chemical Equilibrium?

The combustion reaction that happens in a car's engine goes in only one direction. This is shown by the arrow in the equation that points from the reactants to the products.

$$2C_8H_{18} + 25O_2 \longrightarrow 18H_2O + 16CO_2$$

Because the reaction goes in only one direction, the reactants must always be present for the reaction to continue. For this reason, a car will stop running if there is no gasoline in the fuel tank.

Not all reactions go in only one direction. Some reactions occur in both directions. These reactions are reversible. A reversible reaction is shown in a chemical equation by arrows that point in both directions.

$$\text{reactants} \leftrightarrows \text{products}$$

Equilibrium can be described as a balance that is reached by two opposing forces. A reaction that proceeds equally in both directions is in a state of **chemical equilibrium**. The rates of the forward reaction and the reverse reaction are equal. ☑

To help you understand equilibrium, think of a football game. Eleven players from each team are on the field at one time. If one player enters the game, then another player from the team must leave the game. Even though changes are made, each team always has 11 players on the field. Therefore, the teams are in equilibrium.

READING CHECK

11. Compare For a reaction in chemical equilibrium, how do the rates of the forward and reverse reactions compare?

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LOOKING CLOSER

12. Explain Why is the carbonated water no longer at equilibrium when you remove the bottle cap?

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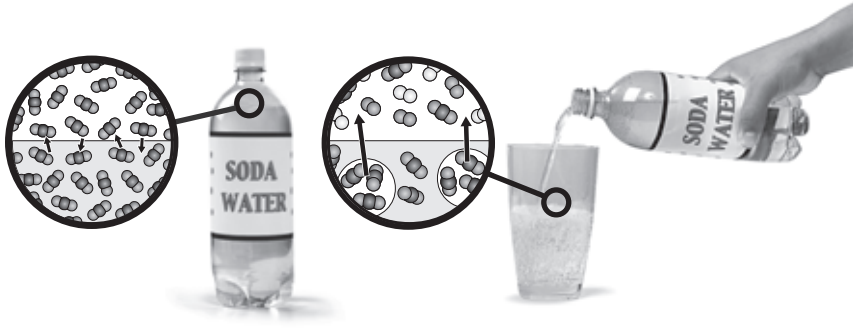

Carbonated water in a closed bottle is at equilibrium. Gas particles dissolve in the liquid at the same rate that they leave it.

If you remove the top of the bottle, gas particles leave the liquid faster than they dissolve in it. The carbonated water is no longer at equilibrium.

A DYNAMIC PROCESS

Chemical equilibrium is a dynamic process. That is, changes happen all the time. However, when a change is made, the chemical reaction adjusts to maintain equilibrium.

Consider the Haber process, which is used to make ammonia, NH_3. Ammonia is a chemical used in fertilizers, dyes, plastics, cosmetics, cleaning products, and fire retardants. The Haber process is shown in the following equation.

$$N_2(gas) + 3H_2(gas) \leftrightarrows 2NH_3(gas) + energy$$

Notice that the process is reversible. However, manufacturers want more NH_3 than N_2 or H_2. In other words, they want to change the equilibrium so that the right side of the equation is *favored*. Some conditions that affect equilibrium are shown below.

The Effects of Change on Equilibrium

Condition	Effect
Temperature	Increasing temperature favors the reaction that absorbs energy.
Pressure	Increasing pressure favors the reaction that produces fewer molecules of gas.
Concentration	Increasing the concentration of one substance favors the reaction that produces less of that substance.

LOOKING CLOSER

13. Apply Concepts What could you do if you wanted to favor an endothermic reaction?

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LE CHÂTELIER'S PRINCIPLE

Le Châtelier's principle is a general rule that describes how equilibrium systems respond to changes.

Le Châtelier's principle

If a change is made to a system at chemical equilibrium, the equilibrium shifts until the system reaches a new equilibrium.

Critical Thinking

14. Apply Concepts What factor would you change in the Haber process if you wanted to favor the left side of the equation? Explain your answer.
(Hint: Use the table in the text above.)

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Look again at the equation for the Haber process above. Recall that increasing pressure favors the reaction that produces the fewer gas molecules. Thus, if you increase pressure, the equilibrium shifts and the right side of the equation is favored. As a result, more NH_3 forms. For this reason, the Haber process is carried out under extremely high pressure.

Name _____ Class _____ Date _____

Section 4 Review

SECTION VOCABULARY

catalyst a substance that changes the rate of a chemical reaction without being consumed or changed significantly **chemical equilibrium** a state of balance in which the rate of the forward reaction equals the rate of the reverse reaction and the concentrations of products and reactants remain unchanged	**enzyme** a molecule, either protein or RNA, that acts as a catalyst in biochemical reactions **substrate** the reactant in reactions catalyzed by enzymes

1. List Identify five factors that may affect the rate of a chemical reaction.

2. Explain If you add a piece of potato to hydrogen peroxide, tiny gas bubbles will form. However, if you crush the piece of potato first, more gas bubbles will form. Explain these observations.

3. Compare What is the relationship between a catalyst and an inhibitor?

4. Predict How will an increase in pressure affect the following chemical equilibrium: $2NOCl\ (gas) \leftrightarrows 2NO\ (gas) + Cl_2(gas)$? Explain your answer.

5. Evaluate Assumptions A person tells you that a reaction must have stopped because the amounts of products and reactants have not changed. What is wrong with the person's reasoning?